PRESERVATION OF HISTORIC STEEL BRIDGES IN VIEW OF ALTERNATIVE USE

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***Abstract**:*
It is generally felt that the character of steel bridges from the first half of the XXth century bridges testifies the craftsmanship both of designers and builders of the past and they should be preserved as being part of the cultural heritage, as much as buildings. In addition, the owners often consider alternative use of the infrastructure, either more heavy load, widening or extension of the roadway. Preservation of this type of bridges has become achievable, because of more detailed and higher performance of analysis tools and assessment and higher performing materials for strengthening. However, the main prerequisite for this is the search for adequate concepts for repair and strengthening as well as the will to actually achieve this goal. Two pending cases are being discussed. The first concerns a steel truss bridge of 60 m span, built in 1906, the second one is a plate girder bridge across river Dender at Oudegem, built in 1951. These bridges have different qualities and can be adapted according to the new situation. However, the future of these two bridges is uncertain.

***Key words**: Early age steel bridge, alternative bridge use, preservation of bridge, historic bridge, load-carrying capacity*

1. Introduction – Threats and opportunities for older steel bridges

Steel bridges from the early or mid XXth century often have shapes that are no longer built today. Their design may either have become too complicated or require too much manual labour to be built. However, it is generally felt that the character of these bridges testifies of the craftsmanship, both of designers and builders of the past and they should be preserved as being part of the cultural heritage, as much as buildings. Concerning their preservation for long life and use, steel bridges have a rather poor reputation, since conservation of the material requires regular inspection as well as maintenance. It is generally felt that other materials, such as concrete behave far better and show less signs of deterioration with time. At many times, the latter proves to be untrue.

However, many of these older bridges, who have reached the end of normal life between 70 and 100 years, no longer correspond to the present requirement of road traffic, and are subject to traffic limitations. Frequently, the solution to this problem is to permanently lower the dead load or impose vehicle mass [1]. In other cases, additional load may be considered, for instance by adding traffic lanes, or by providing other new functions. In both scenarios higher performance of analysis tools allow improved assessment of the bridge condition and load carrying capacity. In addition, higher performance of materials and strengthening processes offer new opportunities and may allow adequate repair of older structures, thus satisfying the required conditions.

In what follows two pending cases of older bridges are being discussed. Various solutions have been considered and seemed realistic. However, the main prerequisite for developing adequate concepts for adaption or repair remains that the owners actually are willing to achieve this goal. Unfortunately the latter happens rarely, as owners tend to decide rather quickly in favour of replacing the structure.

2. Steel truss 60 m span road bridge

This bridge, located near the town of Mechelen (B) allows the crossing of a 2-lane local road across a railway marshalling yard. Initially this yard was much larger than today, which explains the excess of horizontal clearance below the bridge, which can be seen in Fig. 1.

Fig. 1. Truss bridge of 60 m span

Obviously, the concrete parapets, to prevent electrocution by overhead lines, obstruct the view on part of the structure. In the view from the road (right of Fig. 1) the structural lines can be seen more clearly. The number of this type of bridges in Belgium is decreasing rapidly and this is one of the rare specimens left. This bridge was built in 1906 from early age steel and is completely riveted.

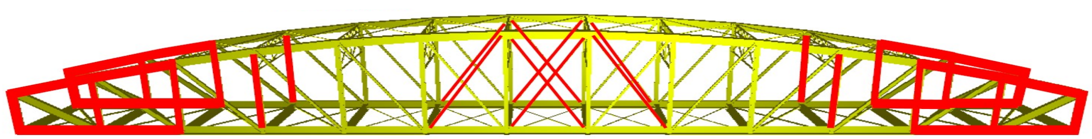

Fig. 2. Members showing insufficient resistance

Careful analysis has revealed that the structure does not comply with present requirement of loads, in particular LM1 from EN 1991-2 [2]. The elements that show insufficient resistance are marked in red (bold) in the scheme of Fig. 2. Apart from the upper- and lower edge members, most of these fails are due to insufficient buckling resistance.

Although the crossbeams suffice to resist the traffic loads and the unity-check equals 0.74, corrosion has reduced their resistance and the check may in fact exceed 1. This has inspired to consider various ways of refurbishment and increase resistance of the structure.

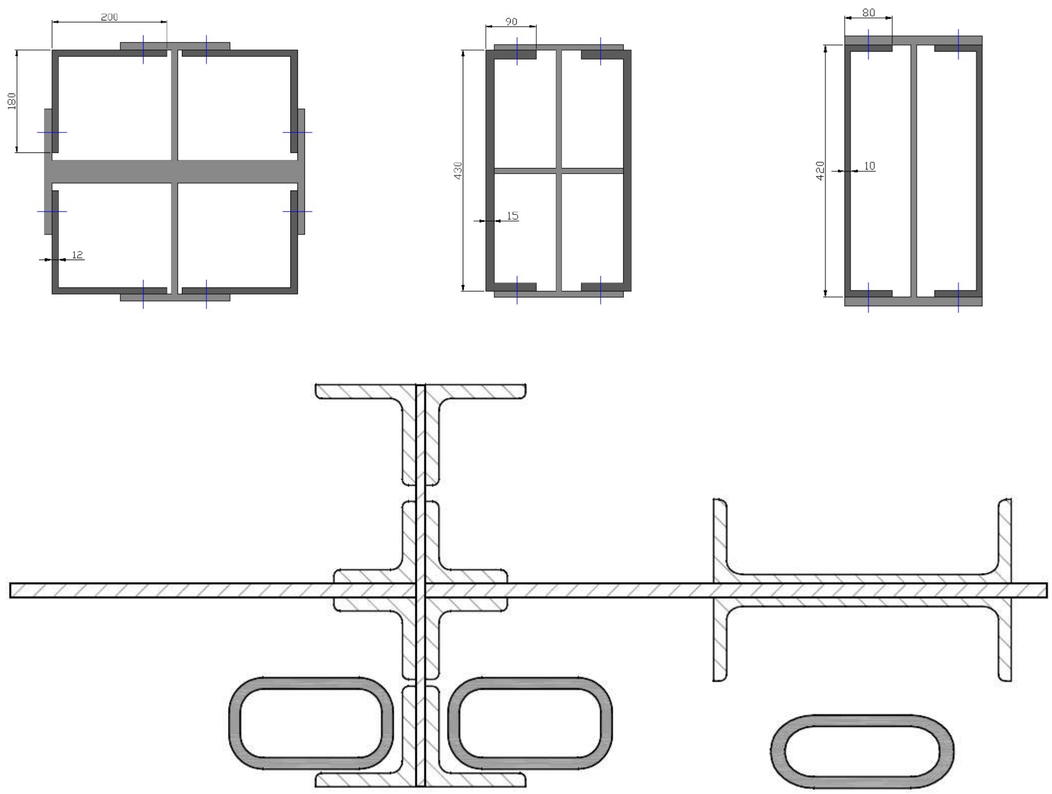

Fig. 3 :Reinforced cross sections

The first method would be to reinforce members by adding several profiles, mostly by closing open member sections. The riveted joints are to be replaced by tension controlled bolts. These have round heads on one side and thus, from one side, are resembling rivet heads. Cross sections would become as shown in Fig. 3 top. However, this is considered to be a hazardous method. The alternative is to build completely independent welded lightweight truss RHS girders of S 460 grade steel inside the hollow spaces of the various members. This requires replacing of the corroded crossbeams. This, from the outside (left of Fig. 1) the view has unchanged and even from the inside only small new parts will be visible. In addition the much too heavy upper bracing may be replaced by a simple connection of a closed section between the two new truss members. The old and new structure are to be connected by steel glue. This connection serves only to reduce the slenderness of the compressed members, thus giving a permanent function of stiffness without actual resistance to the existing trusses.

After long consideration, the owner did not accept these alternatives and chose to demolish this 114 year old and rare structure, taking advantage of the fact that the bridge span can be reduced to 34 m. The new bridge will be a steel tied arch with concrete slab.

3. Adding a bicycle path to a 26 m span railway bridge

For several years now, authorities are promoting modal transportation shift. Cycling is one of the healthiest ways for individual transport. Hence, fast cycling lanes are being built, which obviously will relieve roads from traffic jams and allow higher speed for cyclists. At various locations these fast lanes must cross important roads, waterways and other obstacles. Since the budget is limited, existing bridges are looked for and bridge owners are urged to admit the cyclist path to hang in cantilever from the existing bridge. This obviously constitutes additional vertical load on the bridge and also introduces torsion moments. Depending on the type of bridge, the latter may have serious implication on the bridge load carrying capacity. If the project can be worked out simultaneously with building a new bridge, the solution is evident, as shown in Fig. 4, the crossing of river Nete between Antwerp and Brussels [3]. However, if the structure has a rather inadequate character for resisting torsion, conditions may become critical.

Fig. 4 :Corbelling cyclist path at crossing of river Nete

The railway crossing of river Dender near Oudegem (B) was built in 1951 as two single track plate girder bridges of 26 m span. The river itself is rather narrow at this location, although the confluent with river Scheldt is near. The fast cycling lane from Mechelen to Ghent crosses the river at this particular location. Hence, the idea was to build a 2.6 m wide corbelling structure and connect this to the Northern single track bridge.

Fig. 5 shows this typical bridge, built of steel AE 235, the older name for the present S 235. This material has similar characteristics, but the variation of stress characteristics is wider and a more cautious value for f_{yd} must be adapted.

Fig. 5 :North and inside view on River Dender bridge near Oudegem

Closer views on parts of the bridge show at first sight rather serious corrosion. In addition, a problem seems to have occurred to the movable bearings. The latter certainly is outside the present discussion. For these reasons, the owner has put this bridge under reinforced surveillance. However, apart from local defects, presumably the appearance of the bridge is more worrying than the actual corrosion damage.

Apart from additional vertical load, adding the bicycle path introduces longitudinal torsion of the plated girder. The latter has but small torsional resistance, since this is provided by out of plane bending of the web and its vertical stiffeners. Hence, also lateral torsional buckling, as well as plate shear buckling have to be considered. As shown in Fig. 6, no clear lateral torsional stability mode is found, since it interacts with local plate buckling.

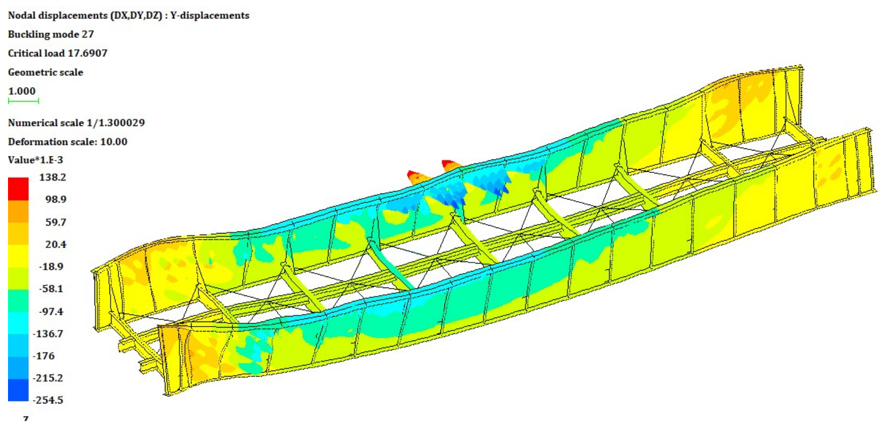

Fig. 6 : Lateral torsional buckling mode

In addition, the lateral torsional slenderness of 0.273 is below the limiting value of 0.4 and further influence of the stability mode does not have consequence on the stress magnitude. The analysis has shown that the corbelling cyclist path may increase the stress level with 40.7 % especially because of the skew of the upper flange of the closest plate girder. This effect is entirely due to the poor lateral resistance of this type of structure and could be expected right from the start. Although the unity-check of stress conditions in ULS is limited to 0.95, the project has been put on hold. In spite of its fundamental flaw, the owner seems not to be opposed to the project and has decided to inspect the structure more thoroughly, in view of determining possible deterioration due to corrosion. Plate and profile thickness are to be measured to further decide on the future of this project.

From the point of view of preservation of interesting structures, testifying to construction techniques from the past, the river Dender bridge may be worth maintaining. It certainly is not an aesthetical structure, and does not compete with more complex and exuberant bridges [4]. The number of this type of bridges having decreased dramatically over time, it may however become one of the rare examples of plated girder bridges in Belgium.

Conclusion

The 60 m span truss girder bridge in Mechelen certainly is a structure, reflecting the ideas and craftsmanship of early 20th century. The complicated composition of riveted plates and angle profiles and the open character of cross sections, necessary for riveted connections, are rarely found. The latter allow reinforcement inside these open sections, by using modern welded high-grade hollow members. The existing structure would then remain useful for increasing lateral stability of the compressed members. This proposal has been rejected because of the presumed high cost and the bridge will be replaced in the near future.

The river Dender bridge certainly shows less quality and is more recent, although it is already 70 years old. This massive structure does not appeal to an aesthetical mind, probably because of the plain and flat shape and the simplicity. The alternative use might well be an opportunity to extend the lifespan of this bridge.

For both cases, modern simulation technology always offers solutions to give older constructions a longer life. This may be useful while discovering efficient preservation methods for valuable historic structures.

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